Study and characterization regarding phytoremediation potentiality of *Tagetes erecta* Linn. to decontaminate the fly ash polluted soil

Submitted by

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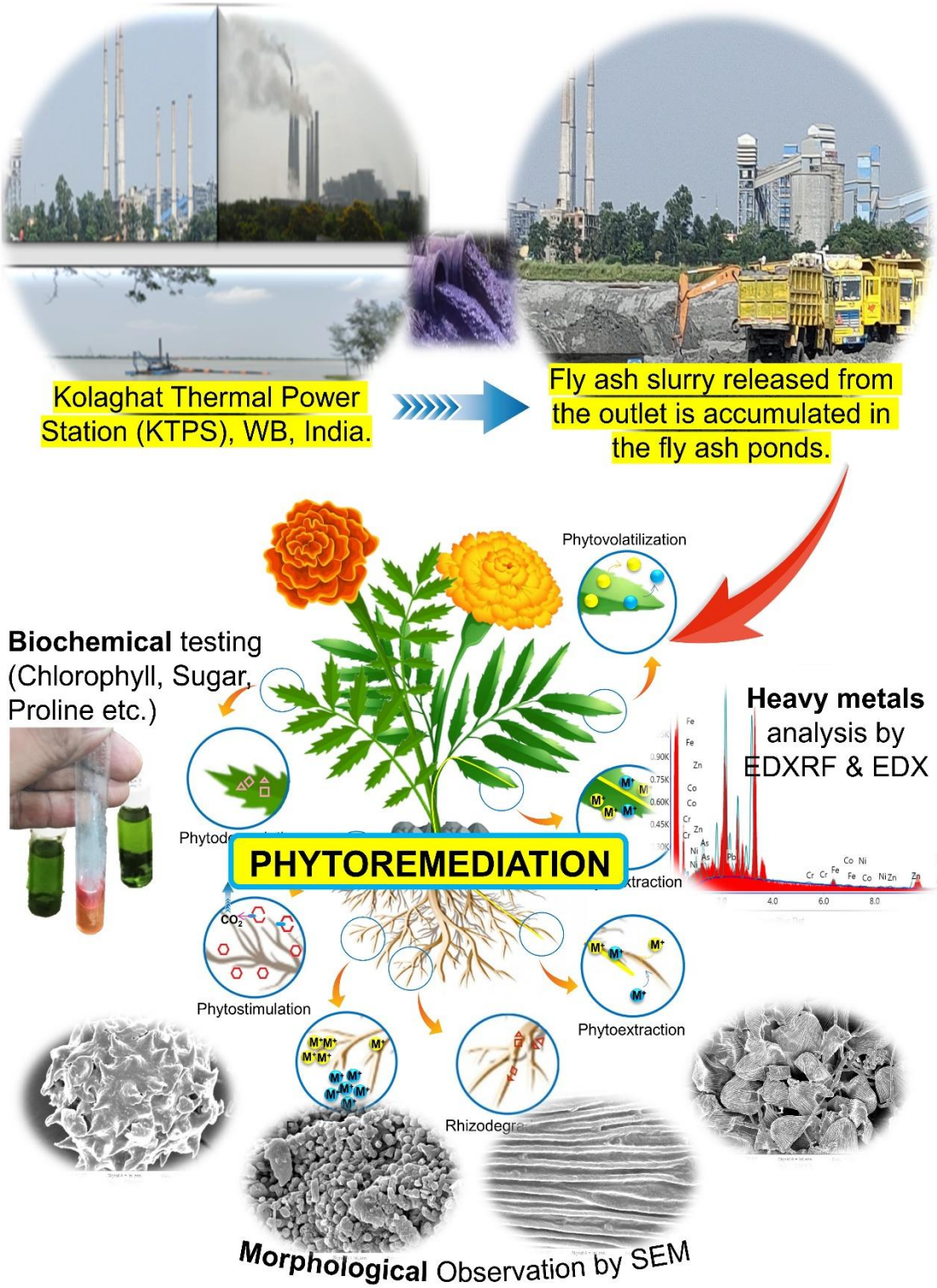
Graphical Abstract


Kolaghat Thermal Power Station (KTPS), WB, India.
Fly ash slurry released from the outlet is accumulated in the fly ash ponds.
Phytovolatilization
Biochemical testing (Chlorophyll, Sugar, Proline etc.)
Heavy metals analysis by EDXRF & EDX
PHYTOREMEDIATION
Phytostimulation
Phytoextraction
Rhizodegra
Morphological Observation by SEM

Abstract

The second largest thermal power station in West Bengal is Kolaghat thermal power station (KTPS), geographically located (22°24′56″N, 87°52′12″E) at Purba Medinipur district of West Bengal, where a huge amount of fly ash is generated and accumulated over a long period. The primary aim of the study was to determine the preliminary account of soil health conditions related to the physicochemical and microbial attributes of KTPS surrounding areas. Also, the study used different percentages of fly ash amended soils. Energy Dispersive X-ray Fluorescence (EDXRF) analysis revealed significantly elevated concentrations of heavy metals/metalloids (Pb, As, Cr, Ni, Co, Zn, and Fe) in the fly ash and contaminated soils compared to control samples. A high-performance silicon drift detector was used under a helium atmosphere to enhance sensitivity for lighter elements like P and K, while optimized excitation conditions facilitated the detection of heavy metals. Field Emission Gun-Scanning Electron Microscopy (FEG-SEM) images confirmed that fly ash particles were predominantly spherical with non-uniform sizes.

Due to the incorporation of fly ash, various physicochemical characteristics like pH, EC, bulk density, organic matter, water holding capacity, and NPK ratio were altered from the control soil, affecting the nearby agricultural land. Microbial activity was also changed with the alteration of different physicochemical properties of the soil. Colony-forming units were used as a common indicator of microbial biomass. It was found that bacterial activity was higher in all of the collected fly ash-contaminated soil (FCS) samples, and maximum colony-forming units were calculated in 30% amendment of fly ash.

Phytoremediation is now regarded as a promising set of techniques that utilize specially selected plant species to remove, degrade, stabilize, or isolate pollutants from soil and water, contributing to environmental cleanup. Recent advancements highlight the use of non-edible ornamental plants for their dual role in heavy metal removal and aesthetic enhancement of polluted areas. In this study, the homogenous seedlings of the selected plant species (*Tagetes erecta* Linn) were grown in different collected Fly ash contaminated soils, differently amended Fly ash contaminated soils,

and control soil. All the plants were harvested at the 90^{th} day from the day of plantation. Data regarding different morphological parameters, viz. root length, shoot length and plant height, number of branches, number of leaves, maximum leaf length, period of first budding, and inflorescence diameter, etc., were taken to determine the morphological responses of *Tagetes erecta* Linn. The ninety-day-old, harvested plants, grown in different treatments as per experimental design were allowed for biochemical studies as well as for testing of the heavy metal contents in the different plant parts. Based on the experimental result *Tagetes erecta* Linn., was demonstrated here as strong adaptable to heavy metal stress of Pb, As, Cr, Ni, Co, Zn, and Fe up to 30 - 40 %level of fly ash contamination. At a 30% fly ash contamination level, the plant species showed a considerable ($p \leq 0.05$) improvement in growth and development, along with higher total chlorophyll, chlorophyll-a, chlorophyll-b, total sugars, and starch. Concentration of enzymatic antioxidants (such as catalase and superoxide dismutase) and non-enzymatic antioxidants (like proline and ascorbic acid) was elevated to lessen oxidative stress brought on by the hazardous heavy metals in fly ash-contaminated soil. But, in terms of relative biomass, there was a significant reduction at higher fly ash contamination levels (over 30%), highlighting the negative impact of heavy metals on plant species.

FEG-SEM imaging of plant tissues (root, stem, leaf, and flower) from 30% fly ash-treated samples, supported by Energy Dispersive X-ray (EDAX) analysis, confirmed the accumulation of the studied metals. Therefore, the plant can accumulate the specific metals, including arsenic (As), nickel (Ni) and zinc (Zn), with a maximum bioaccumulation factor for roots (BAF_{Root}) exceeding 0.50, while zinc exhibits a BAF_{Leaf} value greater than 1.

The study suggests that phytoremediation approach may be implemented as a sustainable management strategy, and the plant species, *Tagetes erecta* Linn. can be effectively used in crop rotation to sustainably remediate fly ash-contaminated soil.